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KANSAS UNIVERSITY SCIENCE BULLETIN.

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DISTRIBUTION OF KANSAS CRAYFISHES.

BY J. ARTHUR HARRIS.

With map.

IN the brief paper here presented, it is my purpose to bring up to date my catalogue of the crayfishes of Kansas[1] by the addition of such localities and notes as have been collected since its appearance; to represent by means of a map the distribution by counties of the different species, and to show, so far as is possible at the present time, the distribution of the different species by river systems. The distribution by river systems has been included, since I feel that a thorough knowledge of this phase of the subject will be of interest in the determination of the phylogenetic relationship of the different species. Of course, any conclusions as to the distribution of the species by water systems can be only provisional, since more systematic collecting will surely change any such conclusions. It is my desire to put the data available at present into such form that the addition of new data and the deduction of more certain conclusions will be possible with the least amount of labor.

The form of the annotated catalogue has, as far as possible, been retained. No new species have been found in the state, and there has been practically no new literature of a taxonomic nature since the appearance of the catalogue. The synonomy has, therefore, been omitted. In referring to localities reported in the previous paper, I shall designate them by numbers enclosed in parentheses, *C. virilis*, (3), the number being that of the locality as given in that paper—the example given being: *C. virilis*, Wabaunsee county (coll. Washb. Coll.), J. B. Fields, coll. (Faxon, '85, b.)

1. Harris, J. Arthur: Annotated catalogue of the crayfishes of Kansas. Kans. Univ. Quart., vol. IX, No. 4, October, 1900.

I wish to express here my gratitude to my sister, Nellie Harris, without whose kind assistance in this and other work the appearance of this material at the present time would have been impossible. My thanks are also due those who have collected material in various parts of the state.

The greater part of the material belongs to the private collection of the writer, but is deposited at the present time in the museum of the University of Kansas.

1. **Cambarus simulans** Faxon.

I have not seen either of the two lots of material assigned to this species. It will be seen that the territory from which it is reported, while much the same as that from which is taken the material provisionally assigned to *C. gallinas*, lies a little to the west and extends north beyond the Smoky Hill river, while the material provisionally reported as *gallinas* is confined, so far, to the territory drained by the Arkansas.

2. **Cambarus gallinas** Cockerell and Porter.

As in my catalogue, I assign only provisionally to this species material from :

3. A stream near Wichita, Sedgwick county; Mr. Willis Henderson, coll.

4. A slough northeast of Caldwell, Sumner county; T. J. Kinnear, coll.

Mr. Kinnear's material was taken at a small slough four miles northeast of Caldwell. The slough had been dry all summer. It will be remembered that the drought of the summer of 1901 was very severe, but a spring a little distance from the edge still contained a little pool of water, perhaps three feet in diameter, although it had ceased to run into the slough. In this little pool of water a few small crayfish, about one inch in length, were noticed; while none of the small specimens were taken, they undoubtedly belong to the same species as the eight adults secured at the same place.

The specimens were secured in digging a well in the old spring. They had burrowed down through the loose surface soil for from six to thirty-six inches, depending upon whether the burrows were at the center or on the edge of the old basin of the spring. The burrows, which were about two inches in diameter,

went down almost perpendicularly until they came to the surface of a stratum of Wellington shale. Here they were enlarged into almost round chambers, about ten inches in diameter and not more than three inches in height. The burrows were supplied with "chimneys" above. In these chambers the crayfish were found. They were not very active or pugnacious. The whole burrow was, of course, filled with water. The crayfish had burrowed down a little ways into the rather disintegrated shale. The excavations into the shale were conical, about four inches in diameter at the top and four inches deep. Mr. Kinnear thought that, as the shale was somewhat softened by the water, the crayfish had removed it bit by bit. There were about three or four of the main burrows coming from the upper surface terminating in the large chambers as described above. These chambers were then connected by passageways running from one to another.

Two of the specimens were taken August 1, and the other six August 25–27. Two were males and the other six females. All the females were, with one exception, well loaded with eggs, which appear, from an examination with a hand lens, to be in a very early stage of development, and have probably been only comparatively recently laid.

So far as reported, this species is confined to a narrow strip of territory running north for about eighty miles from the southern boundary of the state and drained by the Arkansas river.

3. Cambarus gracilis Bundy.

Specimens of this species are hard to obtain, and this doubtless accounts for its few localities. It is found in the territory drained by the Arkansas (1) as well as that drained by the Kansas river (2).

In August, 1901, I found an adult female of *C. gracilis* in a stagnant pond near Lawrence—the only time I have ever taken an adult specimen in open water during the summer.

4. Cambarus diogenes Girard.

Reported so far only from a limited territory along the Kansas and Missouri rivers, in the northeastern part of the state. As with *C. gracilis*, the difficulty of obtaining material probably accounts for the rarity of the reports on this species.

5. Cambarus immunis Hagen.

Mr. Crevecœur collected *C. immunis* in a stagnant pond on the prairie near Onaga, Pottawatomie county, April 1, 1901.

The pond had been in existence about six years, and had never been known to go dry. The nearest creek was about a quarter of a mile away. They were probably never connected when the water was high in the creek. No fish had ever been taken in the pond, but specimens of *Amblystoma tigrinum* (green) were found. (*A. tigrinum* and *C. immunis* are sometimes found in the same ponds in Douglas county.)

Among a dozen specimens given to me, some of the females were carrying eggs but none were noticed with young.

Mr. Crevecœur drained the pond in obtaining the material, and was careful to secure a representative collection. If *C. gracilis* were common in the region, it would not be improbable that females would be found in the pond at this time.

Reports so far would indicate a distribution of this species from the Missouri river west along the Kansas and its tributaries nearly two-thirds the distance across the state.

5a. Cambarus immunis Hagen, var. spinorostris Faxon.

The limits of distribution are embraced within those given for *C. immunis*.

6. Cambarus nais Faxon.

So far as reported, this species is confined to the southeastern portion of the state, drained by the tributaries of the Arkansas river.

7. Cambarus virilis Hogue.

23. Wakarusa river, Douglas county.

24. Bull Foot creek, Lincoln county. Taken under stones, in about six inches of running water. Miss Ella Weeks, coll.

25. Spillman creek, Lincoln county. Under stones, in shallow running water. Miss Ella Weeks, coll.

26. Wildcat creek, about two miles west of Manhattan, Riley county.

27. Crayfish are not at all common in the lower part of the Kansas river, at least near Lawrence, where I have had opportunity to observe it. The fishermen, as a rule, say there are

none in the river. I have, however, seen the casts of *C. virilis*, and think it hardly probable that they could have washed in from any of the small tributaries.

No. 18 was collected in a small stream.

8. Cambarus rusticus Girard.

Reported only from Osage river.

9. Cambarus pilosus Hay.

This somewhat questionable species has been reported from two localities comparatively close together in the north-central portion of the state.

Mr. Sutton informs me that his material (2) was collected in Kelos Fork, a "wet weather" stream of fresh water which flows into Salt creek, which empties into the Saline river about four or five miles from where the specimens were taken. At the time the material was taken there was no water flowing from the pools into the creek. During the summer of 1901, Mr. Sutton took material from a well about five feet in depth, near the above region. The water from the pools would overflow into the well when the water was high.

10. Cambarus neglectus Faxon.

4. Wildcat creek, about two miles west of Manhattan, Riley county. Collected with the specimens of *C. virilis* mentioned above. Presented by J. N. Westgate.

C. neglectus, so far as reported, is quite closely confined to the Republican river valley. The Republican river drains Cheyenne (2) and Decatur (3) counties. Mill creek (1), in Wabaunsee county, empties into the Kansas river about fifty miles east of the Republican. Cat creek (4) empties into the Kansas river about twelve miles from the Republican. Tributaries of the Republican approach to within six miles of the upper part of Cat creek, but I know nothing of the nature of the country separating these streams.

With the exception of the Republican river, in Cheyenne county (2), *C. virilis* has also been taken from all the above localities.

The Republican river, in Cheyenne county, wherever I have seen it, is a shallow stream, perhaps 50 to 100 feet wide, with a

bed of loose sand. It sometimes, though rarely, goes dry in places so far as the surface is concerned, but it is said that water can always be found by digging a few inches into the sand of the bed.

During the early part of June, 1901, while near Springfield, Greene county, Missouri, I had the opportunity of making a few observations on the habits of *C. neglectus*. In the James river, near Galloway, about eight miles southeast of Springfield, this was the only species observed, although probably not the only one occurring in the river. At this place the James river is a rather swift-flowing stream, with a rocky bed and with rather high wooded hills along the sides. The stream is quite shallow in the swiftly running places. The crayfish were quite abundant, being found under the loose stones and resting in the strands of the rich vegetation, which stood almost horizontal in the swiftly flowing water.

The specimens were very plentiful around Boiling Springs, a place where one of the cold, underground rivulets of the region breaks through the rocks in the bottom of the stream.

In a clear, rocky stream,[2] shallow in most places, flowing between high hills, about four miles northwest of Springfield, crayfish were found in abundance. The smaller and by far the more numerous species was *C. neglectus*. The animals were very active, darting from stone to stone when disturbed, but usually remaining under cover but a short time.

In a stream flowing from Galloway Cave, at Galloway, Greene county, *C. neglectus* and *C. rusticus* were taken. At the mouth of the cave, *C. neglectus* was by far the more abundant, if not the only species, being found in great abundance under loose stones at the very mouth. The water here has practically the same temperature as that on the inside. The temperature on the inside of the cave is said to remain at fifty-seven degrees F. winter and summer. The animals were very inactive, the cold water, apparently, numbing them to such an extent that it was not at all difficult to take them with the hand.[3] A little distance down the stream, where the water was much warmer, the animals were noticed to be as active as ever.

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2. I am not sure, in a trip across country, which of the two creeks, which flow together in this vicinity, I examined.

3. The water here is probably not more than fifteen degrees above that in which *C. virilis* was found to be so numb as to be almost incapable of movement. See Harris, Annotated Catalogue.

A striking effect of the low temperature was noticed in the effect on the hatching of the eggs. Many of the females taken at the mouth of the cave carried eggs or recently hatched young, while none of those taken in the other localities were found with young at all. I believe I found young crayfish which had but recently left the female in the vegetation near Boiling Springs, in the James river.

In the table following, the distribution by river systems of the different species is given. For convenience, the rivers of the state from which material has been reported have been arranged as follows:

MISSOURI RIVER
KANSAS RIVER
- Big Blue River
- Republican River
- Solomon River
- Saline River
- Smoky Hill River

OSAGE RIVER
ARKANSAS RIVER
- Medicine Lodge River
- Chikaskia River
- Little Arkansas River

The tributaries of any stream are arranged in order, beginning with the lower and passing towards the upper portion of the stream. Those tributaries emptying outside the state are designated by an asterisk.

When it is impossible to determine from which of two or more streams a lot of material is reported, as is often the case when the localities given is a country traversed or drained by two rivers, or a town situated on some large stream, or where two streams join, it is reported from each, with the catalogue number followed by a question mark. Of course, in the greater number of these cases, the species will be found to occur in greater or less numbers in each locality. The one thing to be desired is, that collectors would furnish full data with their material.

Whenever possible, the name of the stream from which ma-

terial was taken is given. When this is not possible, the term "tributary" is used. As a general rule, the tributaries are streams emptying directly into the river under which they are placed, and the only exceptions to this, I believe, are the tributaries of the Arkansas arising in the southeastern corner of the state. Stagnant ponds in the region drained by a stream have been classed as tributaries, even through they have no direct connection.

The above method of classifying the water systems of the state will, very possibly, be found not the best for a final arrangement, but for a preliminary classification—and nothing more than a preliminary arrangement can be hoped for at present—it seems quite satisfactory.

MISSOURI RIVER, *C. virilis*, (5?).

Tributaries, *C. virilis*, (5?), (22), (20?); *C. diogenes*, (1); *C. immunis*, (1).

KANSAS RIVER, *C. virilis*, (3?), (6?), (11?).

Tributaries, *C. virilis*, (1), (3?), (6?), (11), (18), (20); *C. gracilis*, (2); *C. diogenes*, (2); *C. immunis*, (2); *C. immunis*, var. *spinorostris*, (2).

WAKARUSA RIVER, *C. virilis*, (23).

Rock creek, *C. virilis*, (14).

Washington creek, *C. virilis*, (15).

Coon creek, *C. virilis*, (16).

Wildhorse creek, *C. virilis*, (17).

Ward's creek, *C. virilis*, (2); *C. immunis*, var. *spinorostris*, (1).

Mill creek, *C. neglectus*, (1).

Wildcat creek, *C. virilis*, (26); *C. neglectus*, (4).

REPUBLICAN RIVER, *C. virilis*, (7); *C. neglectus*, (2).

Sappa creek, *C. virilis*, (9); *C. neglectus*, (3).

SOLOMON RIVER, *C. pilosus*, (1?).

Tributaries, *C. pilosus*, (1?).

SMOKY HILL RIVER.

Big creek, or tributary to it, *C. simulans*, (2); *C. immunis*, (2); *C. virilis*, (8).

SALINE RIVER.

Bullfoot creek, *C. virilis*, (24).

Spillman creek, *C. virilis*, (25).

A tributary of Salt creek, *C. pilosus*, (2).

OSAGE RIVER, *C. virilis*, (10); *C. rusticus*, (1).

ARKANSAS RIVER, *C. virilis*, (4 ?).

*Tributaries, *C. nais*, (1); *C. gracilis*, (1).

Tributaries, *C. virilis*, (4 ?); *C. gallinas*, (3).

*Coal creek, *C. nais*, (2).

*Labette creek, *C. virilis*, (21).

CHIKASKIA RIVER.

Tributary, *C. virilis*, (9); *C. gallinas*, (2), (4).

LITTLE ARKANSAS RIVER.

Tributary, *C. gallinas*, (1).

MEDICINE LODGE RIVER.

Tributary, *C. simulans*, (1).

LABORATORY OF ZOOLOGY AND HISTOLOGY,
UNIVERSITY OF KANSAS.

CHEYENNE 10
10 RAWLINS
DECATUR 7
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL 9
CLOUD
CLAY
7 RILEY 10
POTTAWATOMIE 5
JACKSON
ATCHISON
JEFFERSON 7
7 LEAVENWORTH 5 4
WYANDOTTE 7
WALLACE
LOGAN
GOVE
TREGO
1 5 ELLIS 7
9 RUSSELL
7 LINCOLN
OTTAWA
7 CLEARY
7 WABUNSEE 10
5 SHAWNEE 7
5 DOUGLAS 3 7 4
JOHNSON
SALINE
DICKINSON
MORRIS
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
ELLSWORTH
RICE
McPHERSON
MARION
CHASE
LYON
OSAGE
FRANKLIN
MIAMI
7 FINNEY
HODGEMAN
PAWNEE
HAMILTON
KEARNEY
EDWARDS
STAFFORD
RENO
HARVEY 2
BUTLER
GREENWOOD
COFFEY
ANDERSON
8 LINN 7
WOODSON
ALLEN
BOURBON
GRAY
FORD
STANTON
GRANT
HASKELL
7 KIOWA
PRATT
KINGMAN
SEDGWICK 2
ELK
WILSON
NEOSHO
CRAWFORD
MORTON
STEVENS
SEWARD
MEADE
CLARK
COMANCHE
1 BARBER
HARPER
7 SUMNER 2
COWLEY
CHAUTAUQUA
6 MONTGOMERY
7 LABETTE 3 6
CHEROKEE

OBSERVATIONS ON THE POLLINATION
Of Solanum rostratum Dunal and Cassia chamæcrista L.

BY J. ARTHUR HARRIS AND OSCAR M. KUCHS.

With Plate I.

IN 1882 Professor Todd published his interesting observations[1] on the pollination of *Solanum rostratum* and *Cassia chamæcrista*. Since that time, so far as the writers are aware, nothing has appeared upon this subject. During the months of August and September, 1901, opportunity was afforded the writers for making more extended observations on these species. The notes here given are the result of these observations. In some respects, these observations, or the conclusions drawn from them, differ essentially from those made by Professor Todd; in others they are practically the same. The writers feel that, even where observations or conclusions are the same, the confirmation of Professor Todd's results is of value, since the data have been collected in a different locality and a different year.

It must be borne in mind that the lack of agreement between the observations in the present paper with those made by Professor Todd is probably largely due to the inferior quality of his material. *S. rostratum* had been but recently introduced into southern Iowa when Professor Todd's article was written. It apparently did not thrive very well, the greatest number of flowers mentioned as appearing on any one plant being ten—a very small number to be produced by a plant of any considerable size. While also an introduced plant in eastern Kansas, it has been long and well established, and grows luxuriantly.[2]

The data upon which the conclusions here given are based have been given largely in tabulated form. For the present purpose, it might have been sufficient to give only the summarized results of some of the tables. They have, however,

1. Todd Prof. J. E.: On the Flowers of *Solanum rostratum* and *Cassia chamæcrista*, Amer. Nat., vol. XVI, pp. 281-287, 1882. A brief review of Todd's paper is given by Dr. P. Knuth, Handbuch der Blutenbiologie, Leipzig, 1898.

2. According to Carruth—Carruth, J. H., Catalogue of Plants seen in Kansas, with additions by Prof. F. H. Snow and Prof. E. Hall—*S. rostratum* first appeared in Kansas in 1864. This date probably refers to eastern Kansas. Dr. S. W. Williston informs the writers that it appeared around Manhattan in 1860 or 1861.

been inserted in full, since the writers hope that they may be useful in future work on these plants, and since they believe that the collection of carefully prepared statistical data of this kind is very valuable for the decision of some biological questions.

The writers wish to express their gratitude to W. C. Stevens, professor of botany, for suggestions on the work, and to Hugo Kahl, entomologist of the University of Kansas, for the identification of the insects. The drawings were made by Miss Marguerite E. Wise.

S. rostratum is a low, spreading, bushy annual, sometimes attaining a diameter of four or five feet and a height of one and one-half feet.[3] The pinnately lobed leaves, as well as other parts of the plant, are beset with strong prickles. It seems to be especially adapted to arid regions, thriving on the dry plains of the Southwest.[4]

The material studied by the writers grew, for the most part, in clayey soil, around old stone-quarries on Mount Oread, a projection of the Kaw river bluffs. A brief examination was made of material growing in waste places in St. Joseph, Mo.

During the very severe drought, which extended up to August, *S. rostratum* was one of the few plants which were apparently uninjured and blossomed with any considerable vigor. The most of the observations were made after the drought was broken by the rain of August 9, when the plants were in the height of their flowering season.

The flower has a somewhat irregular, wheel-shaped, gamopetalous corolla, bright yellow in color. Four of the stamens are normal in their structure, but the fifth, which is on the lower side of the flower, has attained a length almost twice that of the others. Its anther is large and tapering. At about the middle it is crooked a little toward the outside, and its slender, tapering apex is curved upward. The filaments of all the stamens are very short, bringing the anthers close up to the base of the corolla. The small anthers are of about the same color as the

3. One specimen observed growing in rich soil back of a feed-store in St. Joseph, Mo., in early September had a diameter of over seven feet and a height of three feet. The plant might be considered as normally developed, having produced apparently the normal number of seed pods, and so would not be classed with the rank vegetative development which plants sometimes show when grown in very rich soil.

4. *S. rostratum* appears to be better adapted to xerophytic conditions by its extensive root system than by any adaptation for the prevention of evaporation of water. When cut down on a warm day, the plants wilt in a very few minutes. Roots extend down sometimes for more than three feet, so that the plants generally appear perfectly fresh when others around are wilted and drying up.

corolla, varying sometimes to a greenish yellow. The large anther, however, is quite different; the proximal half being of a greenish yellow, while the distal half has a more or less pronounced purple color. Professor Todd, in his paper, does not speak of the color of the anthers, but Fritz Mueller,[5] in writing of *S. rostratum*, says: "All the anthers, as I am informed by Professor Todd, are of the same dull yellow color." All the material examined by the writers from this locality shows a decidedly different color for the distal half of the large stamen. It seems hardly probable that material growing in Iowa should show such a marked difference, but in case this statement is not the result of an oversight on the part of Professor Todd, it is of considerable interest. The anthers dehisce by terminal pores, as is common in the genus to which the plant belongs.

The two lower lobes of the corolla are produced into short wings, which in the bud enfold the pistil and the large stamen, which is clearly differentiated as such in the youngest buds in which the stamens may be discerned by careful dissection. In the bud the pistil lies immediately above the large stamen, but upon the opening of the flower extends between the filaments of the large stamen and that of the small stamen either to the right or to the left.

Professor Todd's statement is: "The pistil in any flower turns toward the axis of the raceme." While in a general way this is true, the statement might be more clearly expressed, since it is only in the general direction of the pistil as a whole that it points toward the axis of the raceme.

The style is not inserted perfectly perpendicularly upon the top of the ovary, but bends slightly downward from the longitudinal axis of the flower. Professor Todd has overlooked this point in his figure. Throughout the remainder of its course until near the tip it is almost straight. Thus it will be seen that the large stamen and the pistil are placed almost opposite each other on the lower side of the flower. The angle between their incurved ends, which approach within about three mm. of each other, is about seventy degrees, thus causing them to point toward opposite sides of the flower. Thus it will be seen that, since the flowers are arranged alternately on the opposite sides

5. Mueller, Fritz: Two Kinds of Stamens with Different Functions in the same Flower, Nature, vol. XXVII, pp. 364, 365, 1883.

of a simple, bractless raceme, and the tip of the large stamen always points toward the axis of this raceme, the flowers on the opposite sides of the raceme have both the stigma and the pores of the large stamen turned in opposite directions.

Professor Todd says: "The flowers are arranged on simple, bractless racemes which extend in a horizontal position." The material examined by the writers does not quite agreee with this observation, the most of the racemes extending upward at a considerable angle. Ten racemes from different plants were selected at random and their angle above the horizontal taken. From the table, it will be noted that the nearest approach to the horizontal is fifteen degrees above, one raceme is vertical, and the average of the ten is fifty-seven degrees above the horizontal.

TABLE A.

I	65°	VII	60°
II	75°	VIII	80
III	45°	IX	50°
IV	90°	X	45°
V	15°		
VI	45°	Average	57°

The terminal portion of the raceme, bearing the buds, is strongly decurved, so that unopened buds obstruct in no way a clear view of the conspicuous flowers, which thus appear to be terminal. The racemes, when in flower, are so far to the outside that the flowers are very little screened by the foliage, whose dark green background renders them more conspicuous.

The fact that the racemes extend upward at some angle from the horizontal, by bringing the flowers above the foliage, renders them more conspicuous.

The terminology used throughout this paper is the same as that suggested by Professor Todd. Those flowers in which the pistil as a whole extends towards the right hand, facing in the same direction as the flower, will be called right-handed, and those in which the pistil as a whole extends toward the left, left-handed. It will be seen that, since the tips of pistil and large stamen approach each other, as above described, the tip of the pistil in a right-handed flower turns considerably toward the left, and *vice versa*. The flowers on the right-hand side of the raceme, as we pass out from the central axis of the plant, are always left-handed, and those on the left side, right-handed.

Professor Todd found from the examination of a small series

of material that about an equal number of right- and left-handed flowers is produced. He also says: "It is also a fact of observation that the flowers of a cluster on any one branch and opening about the same time are either all right-handed or all left-handed. Any plant, however, if it is at all large, exhibits right- and left-handed flowers in about equal numbers."

The regularity with which the flowers are divided into the two classes is very striking. Table B shows the condition of ten plants observed at the same time.

TABLE B.

Plant.....	I.....	7	pistils right-handed,	7	left-handed.
"	II.....	6	" "	6	"
"	III.....	8	" "	9	"
"	IV.....	29	" "	31	"
"	V.....	11	" "	7	"
"	VI.....	10	" "	7	"
"	VII.....	10	" "	13	"
"	VIII.....	3	" "	3	"
"	IX.....	3	" "	2	"
"	X.....	6	" "	9	"
Total..	10	93	pistils right-handed,	94	left-handed.

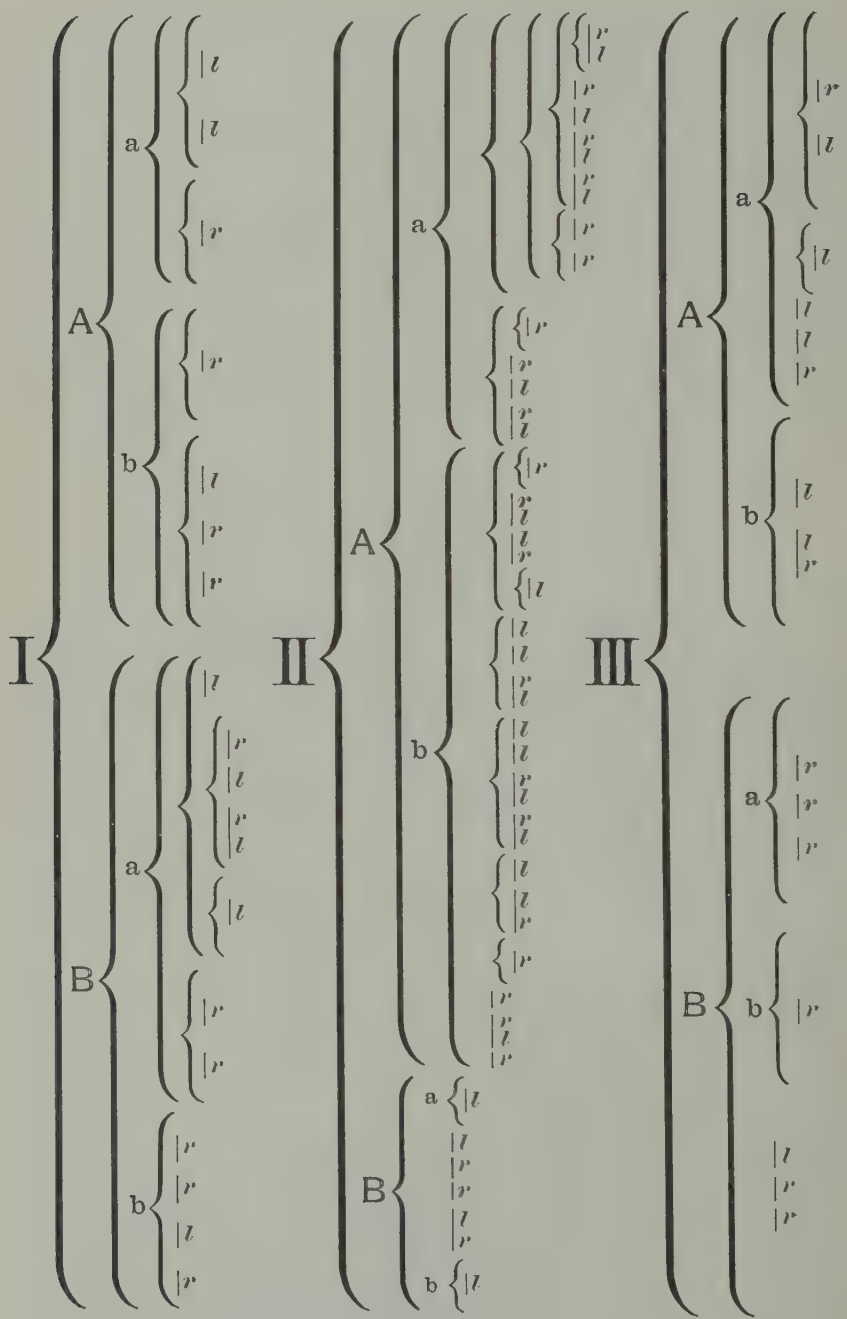
So in these ten plants the number of right- and left-handed flowers is practically equal. The greatest difference in the number of the two kinds is seen in number X, where forty per cent. are right-handed and sixty per cent. left-handed.

Considerable care was exercised in determining the number of right- and left-handed flowers opening on the racemes of different branches at the same time.

Only those flowers were considered which had opened simultaneously. In order to effect this, all the flowers were removed from the plant the evening before and note was made of the condition of those opening the next day.

The following diagram shows the conditions of flowers opening on three plants on the morning of August 20, braces indicating the branches of the plant, and the straight lines the racemes; the numbers of right- and left-handed flowers being indicated under the raceme by *r* and *l*. (See page 20.)

From the table, it will be seen that there are on the first plant 8 left- and 11 right-handed flowers; on the second, 24 left- and 27 right-handed; on the third, 7 left- and 9 right-handed flowers. The numbers of right- and left-handed flowers occurring on the divisions a and b of the main branches, A and B, of the three plants, are as follows:


I
A
a
b
B
a
b
II
A
a
b
B
a
b
III
A
a
b
B
a
b

I.—Aa, 2*l*, 1*r*; Ab, 1*l*, 3*r*; Ba, 4*l*, 4*r*; Bb, 1*l*, 3*r*.
II.—Aa, 8*l*, 13*r*; Ab, 13*l*, 11*r*; Ba, 1*l*, Bb, 1*l*; B, 2*l*, 3*r*.
III.—Aa, 4*l*, 2*r*; Ab, 2*l*, 1*r*; Ba, 3*r*; Bb, 1*r*; B, 2*r*, 1*l*.

On the three plants, with 36 racemes bearing branches, there were 18 branches which produced only one kind of flowers. Of these branches, however, 15 bore only 1 flower each. From this it will be seen that the flowers opening at the same time on any one branch are not all either right- or left-handed. In the large branches, A and B, the number of the two kinds is quite evenly distributed; in only one case—branch B of plant III—is a large per cent. of the flowers alike. Even in branches of the second denomination—Aa, Bb—flowers of one kind occur exclusively, where more than one flower is found, only in Ba of plant III.

In addition to the above table, observations were made on three plants to determine the regularity with which they bore right- and left-handed flowers. On three successive mornings the plants had produced:

	I.		II.		III.	
	Right.	Left.	Right.	Left.	Right.	Left.
First morning	7	7	6	6	8	9
Second morning	7	11	10	7	14	17
Third morning	16	10	8	12	13	10
Total	30	28	24	25	35	36

It will be noticed that when a marked excess of flowers of one kind occurs one morning, a somewhat proportionate excess of the other type occurs the following morning. This is of course necessary if an equal number of the two types of flowers are to be produced and, to a certain extent, to be maintained on the same plant; and is to be expected from the alternate occurrence of the two types on opposite sides of the raceme.

The flowers open early in the morning and remain open from three to four days, depending somewhat upon the condition of the weather. Some which were covered with cheese-cloth "tents" were noticed to remain open almost a week. At the end of this period the corolla wilts and falls off, as does also the pistil. The flowers seem to partially close at night.

A limited series of experiments were made to determine if

self-fertilization and cross-fertilization between flowers of the opposite type opening simultaneously on the same raceme are possible.[6]

The writers have not made sufficiently extensive observations to arrive at any general conclusions of value as to the comparative fertility of cross- and self-pollination, either between flowers on the same or different racemes, or between the flowers of different plants, but they have been able to obtain a limited series of definite results which may be of interest.

In making experiments to determine these points, all old flowers were removed from the plants in the afternoon or evening and the plants covered with a small "tent" of cheese-cloth. The cheese-cloth was of a mesh sufficiently small to prevent the access of any insects large enough to effect pollination, while large enough to allow a ready circulation of air and good illumination. The following morning pollination was effected between the flowers which had opened by tapping pollen from the large anther onto a clean glass slip and transferring it to the stigma of the same or another flower. The plant was then again covered and allowed to remain so, except when examined from time to time, until the corolla and pistil had fallen off. The following results were obtained from three plants upon which observations were made:

Plant I.

August 20. (*a*) Twelve stigmas pollinated with pollen from large stamen of the same flower. (*b*) Cross-pollination effected between two flowers which had opened on a raceme at the same time.

August 22. (*a*) Five of the twelve flowers had fallen off. (*b*) One flower had fallen off. The other seemed to be developing.

August 24. (*a*) Five ovaries with their corollas fallen off appeared fresh and healthy and seemed to be developing. Two more of the twelve had dropped off. (*b*) Remaining pod seemed to be thriving.

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6. Experiments for the determination of the fertility of close and cross-fertilization are always interesting, but are of especial interest in the case of a plant such as *S. rostratum*, in which, if the method of pollination described by Professor Todd is the one actually depended upon, cross-pollination is sometimes possible and sometimes impossible on the same raceme. Of course, if, as suggsted in the latter portion of this paper, the method of pollination suggested by Professor Todd is not the only one, these experiments do not have the interest which they otherwise would.

August 26. (*a*) Four of the five ovaries were clearly developing. The fifth appeared doubtful.

September 13. (*a*) Three fully developed pods remained. (*b*) Development of pod arrested when about half grown.

PLANT II.

August 20. (*a*) Four flowers self-pollinated as with plant I. (*b*) Cross-pollination effected on seven racemes between flowers which had opened simultaneously on the racemes.

August 22. (*a*) All yet on. (*b*) One flower of a pair had fallen off.

August 24. (*a*) Two ovaries remained and looked as though they might develop. (*b*) Three pairs fallen off at raceme. The single pod of one pair still remained and looked as though it might develop. All remaining pairs seemed to be thriving.

August 26. (*a*) One pod developing; the other doubtful. (*b*) Single pod of pair developing. Two pairs were thriving; one pair was almost grown. The third pair looked doubtful.

September 13. (*a*) One pod fully developed; the other fallen off. (*b*) One pair fully developed. One each of two other pairs were fully developed.

PLANT III.

August 20. Thirteen flowers marked to see if autogamy takes place.

August 22. All flowers still on the plant.

August 24. All but two flowers had fallen off. One of these seemed to be developing; the other looked wilted.

August 26. One pod was thriving; the other had wilted and fallen off.

September 13. One pod fully developed.

From the structure of the flowers it would seem that self-pollination would be impossible. When the flower is open, the stigma has never been observed to be in contact with the terminal portion of the large stamen. The stamens do not dehisce until after the flower has opened, nor does the stigma come in contact with the tip of the anther in the bud; thus, clistogamy would be out of the question. It appears from the results obtained from plant III that spontaneous self-pollination is possible. Of course, however, the positive result in this one case should by no means be taken as conclusive evidence of self-pol-

lination. At the present, the most logical explanation to be suggested seems to be that, when the flowers partially close at night, the tips of the pistil and the large stamen are brought into contact. This might occasionally occur, but it is by no means always the case. At the time of the writing of this paper, material for the determination of this point is not available, but two or three flowers examined at night during the summer, before the results of the above experiments had suggested the importance of a careful examination of a large series of material, did not show the stamen and pistil in contact. Of course, note will be taken of the fact that in only one out of thirteen flowers on the plant did spontaneous pollination take place. Another suggestion might be that, approaching so near as they do to each other, a puff of pollen might be thrown from the large stamen and fall upon the pistil when the plant is shaken.

In plants I and II, it will be seen that, in the first case, three fully developed seed pods were obtained from twelve flowers the stigmas of which were supplied with pollen from the large stamen of the same flower. In the second case, one fully developed seed pod was obtained from four pollinated flowers—just twenty-five per cent. in each case.

In the cases in which cross-pollination was effected between right- and left-handed flowers opening simultaneously on the same raceme, we find that, in the first, one pod of the two was only half developed at the end of twenty days. Since the pods are normally fully developed in somewhat less than this length of time, and this undeveloped pod appears somewhat dried, its development seems doubtful. In the second case, one pair of seed pods out of seven pairs of flowers crossed were fully developed, and one seed pod from each of two other pairs were fully and normally developed, making four out of fourteen flowers which yielded seed pods—28.5 per cent.

Professor Todd observed only a small humblebee visiting the flowers of this plant. Owing, probably, to more favorable opportunities for observation, the writers have been able to secure other insects collecting pollen.

The following is a list of the species:

Agapostemon texanus Cress. Two specimens collected August 5, at two P. M. The insects were collecting pollen from the small stamens, to which they clung while they forced the pollen

out by pinching the anthers between their fore legs. Pollen was stored on the hind legs. The insect was not seen to come in contact with the tip of the large stamen or the stigma.

Apis mellifica Linn. Taken at two P. M., August 5. They sometimes came in contact with large stamen and pistil, but more often did not touch them at all. Occasionally both stamen and pistil would come in contact with the same side of the insect's body. Short stamens were sometimes approached from above, the large stamen and pistil remaining untouched.

Anglochora pura Say. Taken at 10:30 A. M., August 6. Obtained pollen from the large stamen by alighting on it, crawling to the tips, and collecting it from the terminal pores.

Halictus sp. A smaller insect than the preceding one, but obtained pollen in the same manner.[7]

No humblebees were taken around Lawrence, although many were noticed working on the plants; consequently the names of the species noticed cannot be given. In St. Joseph, Mo., there were taken at three P. M., when bees were not generally seen working on the plant:

Bombus virginicus. One specimen.

Bombus pennsylvanicus. One specimen.

An examination of fifty flowers taken at this time showed from the dented condition of the small stamens that they had all been visited.

Between eight and nine A. M., September 3, when bees were numerous, there were taken:

Bombus virginicus. Two specimens.

Bombus pennsylvanicus. Twelve specimens.

Bombus scutellaris. One specimen.

The writers found that the humblebees were the principal agents effecting cross-pollination. It was observed that the bee in visiting the flower allowed itself to rest on the tips of the extending stamen and pistil, which, being of the same length, came in contact with both sides of the body just in front of the hind legs, these being left perfectly free. The weight of the bee springs down both stamen and pistil.

Professor Todd's theory in regard to the pollination of this plant is as follows: "The weight of the bee so springs down the

7. As will be remarked, the above insects were all taken August 5 and 6. Careful collecting extending over a considerable period of time would doubtless secure many other forms which visit the plant more or less frequently.

flower, that it is quite difficult, on account of the large, flexible corolla, to see just what is done, but repeated observations led me, quite satisfactorily, to this conclusion. The bee seeks the pollen—for the flowers have neither nectar nor odor—and this she uniformly gets from the four shorter stamens; never, so far as I could determine, from the larger one. This she does by seizing each one, near its base, between her mandibles, and with a sort of milking motion crowds the pollen out of the terminal pores; meanwhile, by the movements of her feet, the larger stamen is repeatedly sprung backwards, and as often throws a cloud of pollen on one side of her body; this in a right-handed flower. When she passes to a left-handed flower, which, as was explained above, is very likely not to be on the same plant, the pollen is carried directly to the pistil of that flower, and so on. We have here, therefore, a novel apparatus for cross-fertilization, quite distinct from those that have been most commonly noticed."

A considerable quantity of pollen may be thrown from the terminal pores of the large stamen upon tapping it. It thus seems quite possible that some pollen is thrown upon the side of the insect, as described by Professor Todd. All the meaning of Mr. Meehan's[8] statement is not clear to the writers, but he says, in speaking of Professor Todd's results: "In regard to the manner in which the pollen is extracted, he found that 'this she does by seizing each anther near its base between her mandibles, and, with a sort of milking motion, crowds the pollen out of the terminal pores.' If this were the general way, there would be no necessity for any pollen being ejected from the long stamens, for the stigma would surely receive some during the 'milking' process; and the pore at the apex in the long anther is beyond the line of the stigma, so that on ejection from the pore the pollen would go still farther beyond."

It seems that this statement is of considerable importance for *S. rostratum* as well as for *C. marilandica*. Professor Todd very evidently overlooked the fact that, in securing the pollen from the small stamens and transferring it to the hind legs, the sides of the insect are sure to be well dusted with pollen from these stamens. In the case of *Apis mellifica*, as noted above, there is no certainty that in visiting the flower the same side will be

8. Meehan, Thomas: On the Fertilization of *Cassia marilandica*, Proc. Acad. Nat. Sci. Phila., 1886, pp. 314-318.

turned toward the stamen or pistil. Even in the case of large insects, such as *Bombus*, it would seem that the probability that the stigma will be supplied with pollen from the large stamen exclusively is very small. It seems improbable that *S. rostratum* should depend exclusively upon such an uncertain method of pollination as the projection, by the jarring of a stamen, of a puff of pollen upon the side of an insect, and the subsequent transfer of this pollen to the stigma of a flower of a different type. Of course, it is not improbable that a part of the pollen is furnished by the large stamen, as suggested by Professor Todd, but that fertilization should be effected exclusively by this means seems highly improbable.

The pollen from the large stamen has been shown to be fertile in a certain number of cases, but unfortunately opportunity was not offered for experiments on the fertility of pollen from the small stamens. A rather hasty microscopic examination of fresh, unstained pollen from the large and small stamens reveals no very striking difference in form.

In *C. marilandica*, Meehan[9] found that the large, strong stamens on each side of the pistil served only as a platform upon which the insect could rest while procuring the pollen from the small stamens. He found that the lower stamens, while filled with pollen, did not dehisce of their own account, nor were they opened by the insect.[10]

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9. Meehan, Thomas, *loc. cit.*

10. It must be stated that in a later paper [Robertson, Charles: Flowers and Insects, V. Bot. Gaz., vol. XV, No. 8, pp. 199–204], Charles Robertson does not give the same results as those found by Thomas Meehan. Robertson says: "Two long stamens, one on each side of the style, furnish pollen for cross-fertilization. They have inflated anthers which probably have a bellows-like action, like the long stamen of *Solanun rostratum* and *Rhexia virginica*." Meehan states expressly in his paper that in case of *C. marilandica* he was sure no pollen was ejected, as Todd found for *S. rostratum*, since in the flowers, which were covered with a gauze bag, the membrane at the apex was never ruptured when the stamens were ready to fall. Rebertson describes the method of extracting the pollen in *C. chamæcrista* in a way which is essentially the same as Todd gives for *S. rostratum*. He then says, in speaking of *C. marilandica:* "Four small stamens furnish pollen for the visitors. Bumblebees milk the pollen out of these, using their jaws, as in the case of *chamæcrista*." Meehan says: "Nor was there any draw-out of the pollen, as observed by Professor Todd. It is abstracted solely through the pores; and, although I could see no evidence that such was actually the case, I suspect that fertilization could only occur through some of this extracted pollen escaping from the insect to the stigma." It must be noted here that the method which Meehan describes for the method of opening of the anthers, the pollen being "abstracted solely through the pores," does not agree with the method described by other observers. Leclerc du Sablon, in a paper, "Recherches sur la Structure et la Dehiscence des Anthers," in vol. I of the seventh series of Annales des Sciences Nouvelles, discusses the anatomical modifications of the anther walls, by which dehiscence is secured. His observations cover *Cassia cremophilia* and *Solanum* (sp. ?) His observations do not cover a sufficient number of species to make them of the greatest value in deciding the present points. The author presents, in a condensed form, his results in: Note sur la Dehiscence des Anthers, La Belgique Horticole, vol. XXXIV, pp. 148–150, 1884. Robertson says, in speaking of the central of the three long stamens: "Bees, no doubt, force the pollen out of this as they do from the short stamens." Meehan says: "I watched a mass of plants containing eighty-eight flower-stems on the 30th of July, and the same lot for an hour on the 6th of August, but saw no attempt to get pollen from the longer anthers or to use them in any way but as a platform. It would indeed be hardly possible for the bee to stand anywhere so as to get power to pierce the apical membranes of the longer stamens. When the flower matured and the anthers were ready to fall they were examined—the four short ones were empty sacs—the three lower ones proved that they had not served any purpose to the bees, for they were full of pollen."

The lower stamens and the pistil of the *Solanum* under consideration serve the purpose of a platform when the flowers are visited by the larger bees. It seems to the writers that this is not improbably the function of the greatest importance of the observed arrangements of the stamen and pistil in *S. rostratum*. In *C. marilandica*, the pollen for fertilization, as well as for the attraction of the insect visitor, is furnished by the small stamens, while the pollen produced by the large stamens appears to have no function.[11] The condition is not so specialized in the species of *Solanum* under consideration. Here the pollen produced by the small anthers serves for the attraction of insects and, as it seems to the writers, for fertilization, while the large stamen, in connection with the pistil, serves as a support for the visiting insect, and possibly furnishes some pollen for cross-fertilization.[12]

In reference to the relative amount of pollen produced by a large and small stamen, Halstead has given a note, in his paper in the Botanical Gazette.[13] The material in the hands of the writers at the time of the writing of this paper is not suitable for a verification of Mr. Halstead's results; consequently they are simply quoted on his authority. Even if the amount of pollen produced by the large anther is no greater than that produced by one of the smaller, it is still very considerable, as may be readily seen by tapping it out on a glass slip. He says:

"The single large stamen of *Solanum rostratum*, with its beak-like appearance, is a giant among its fellows, but does not exceed them in the production of pollen, for, while three or four times larger than the others, its thecæ are reduced to narrow, curved lines of mother-cells. The ordinary stamens, on the the other hand, possess unusually large cavities in which the pollen is borne. The giant stamen, in cross-section, is shown at *a*, in fig. 3, while a similar section of an ordinary stamen is shown at *b*. The almost infertile condition of the large stamen reminds one of the structure of the stamens of the cultivated

11. This, of course, in case, as Meehan states, the large anthers do not dehisce. Of course the statement loses entirely its significance if, as Robertson states, the large stamens furnish pollen for cross-fertilization.

12. While the experiments made upon artificial pollination were very limited, it will be seen that the pollen from the large stamen in no case fertilized over twenty-nine per cent. of the flowers pollinated from it. These flowers, however, were on the same raceme; so the low per cent. might be due to this, or to the mechanical manipulation. The suggestion that the pollen of the large stamen is less fertile than that of the smaller ones is at least interesting as a working hypothesis.

13. Notes on Stamens of Solanaceæ, Bot. Gaz., vol. XV, pp. 103-106, 1890.

potatoes. In these, while large and plump, there is almost no pollen-bearing layer, and usually no apical pore opens for the discharge of pollen."

In *C. marilandica*, as Meehan has shown, autogamy is impossible, while in *S. rostratum* autogamy may possibly sometimes take place.

The bee visits the flower for pollen; contrary, however, to the statement of Professor Todd, that "the flowers have neither nectar nor odor," the writers observed that, especially in the early morning, the odor was decidedly pronounced. It was observed that the bee collected no pollen from the large stamen, but took it regularly from the four smaller. This it did by grasping the anthers, one at a time, near the base, and forcing the pollen out through the terminal pores, by pinching it throughout the length between its mandibles. An exception to this in the case of *Agapostemon texanus* Cress. is already noted in the list of species. It will be remarked that our observations on this point correspond in general to those of Professor Todd.

Of course the statement of Professor Todd, that the next flower of the opposite type which is visited by the bee is very apt to be on another plant, loses entirely its significance, since it has been shown that the flowers on a branch are not at all likely to be all right- or left-handed. In visiting the flowers, the humblebees, as a general rule, simply pass to the flower most conveniently at hand, and this flower is very apt to be on the same plant, especially where the plants are at all large. The humblebees especially work vigorously in the early morning. In a patch of *S. rostratum* examined between eight and nine o'clock, in St. Joseph, Mo., nearly all the flowers had already been visited. At this time fifteen specimens of humblebees were taken. A great many flowers would be visited by the bee before it found one which had not already been despoiled of its pollen. In visiting such flowers, the bee would alight for a moment on the pistil and large stamens, as described above, and then pass on to the next flower when it had ascertained that there was no pollen present. In this way over twenty flowers may be visited in a minute. It will be seen that, when the bees are at all numerous and as well dusted with pollen as they usually are, the pistil is almost certain to re-

ceive pollen, and fertilization to be effected, especially if the pollen from the small stamens is functional.

Among other insects found visiting the plant, the honey-bee was most frequent.

As will be noticed from our list, some insects visit the plants without effecting cross-pollination. Those insects which obtain pollen in an illegitimate manner do not secure it from the small stamens exclusively, but almost invariably visit the large stamen as well.

The adaptation of the plant to propagation by the production of seeds is of considerable significance.[14]

A normal plant will produce in the neighborhood of 7000 seeds. In making observations on this point, it was found from five pods examined there was an average of fifty-six seeds.

Pod	1	contained	66	seeds.
"	2	"	53	"
"	3	"	51	"
"	4	"	53	"
"	5	"	58	"
			281	seeds; av., 56.

Pods 4 and 5 were from the same plant but separate racemes; the others were from different plants. In determining the average number of seeds produced by the plant, five plants growing normally and in different localities were observed, with the following results:

Plant	1.....	192	pods.
"	2	50	"
"	3.....	66	"
"	4.....	113	"
"	5.....	210	"

Taking the average of fifty-six seeds per pod obtained above, we see that the plant producing 122.5 pods, the average from the preceding table, would produce about 7000 seeds.

One plant was observed upon which occurred fifty-five to sixty racemes. Allowing the low average of six pods to the raceme, the plant will produce in the neighborhood of 20,000 seeds. Occasionally a very large plant is observed which pro-

14. Observations on the number of seeds produced and the surety of fertilization may be of especial interest, when the wonderful distribution which this plant has attained in recent years is taken into consideration. The original habitat of *S. rostratum* was the southwestern portion of the United States. It has since spread over a large part of the United States, in many places being recognized as a very noxious weed. It is also reported from several European localities. Reports on the destructiveness of the plant as a weed may be found in publications of the agricultural departments, as: Dewey, L. H., A Weed Bulletin, Farmers' Series, No. 28, U. S. Dept. Agr.; Pammel, L. H., Two Noxious Weeds, Bull. Iowa Exp. Sta., 1895. L. H. Pammel, —Distribution of Some Weeds in the United States, especially *Iva xanthifolia*, *Lactuca scariola*, *Solanum carolineum*, and *Solanum rostratum*, Proc. Iowa Acad. Sci., 1895, vol. II, pp. 103-127—gives the eastward migration of this weed up to 1895.

duces as many as 125 racemes. Allowing the same low average of six pods to the raceme, it will be seen that on a plant of this size there will be produced in the neighborhood of 40,000 seeds.

Only a very small proportion of the ovaries fail to develop. Out of the forty-one racemes observed in five plants, taken at random in different localities, results were obtained as follows:

Plant 1,	5	racemes,	53	pods,	4	failed.
" 2,	5	"	42	"	3	"
" 3,	9	"	55	"	5	"
" 4,	11	"	91	"	6	"
" 5,	11	"	121	"	5	"

41 racemes, 367 pods, 23 failed, or 6.2 per cent.

According to these figures, not more than 6.2 per cent. of the ovaries failed to be fertilized.

While *Cassia chamæcrista* is usually abundant in Douglas county, owing, probably, largely to the severe drought, opportunities for study were not nearly so favorable as for *Solanum*. The material studied was found growing, for the most part, in somewhat shaded localities on the banks of Lake View.

Professor Todd has given very well the points in the structure of the flower of this species. He says: "The points that are of interest to us are the sickle-shaped pistil, the stamens with long, rigid anthers opening by terminal pores, and the most of them pointed toward the incurved petal, which is always on the opposite side from the pistil."

The flowers are arranged in small clusters a little above the axils of the leaves. In some cases the axillary bud also develops into a flower cluster. The axillary clusters have been considered separately in the calculations made upon the conditions of the flowers.

Owing to the lack of material, Professor Todd was unable to determine any definite law governing the arrangement of the flowers in *C. chamæcrista*. This the writers have attempted to do. The determination of any law governing the order of development of the flowers in a plant like *C. chamæcrista*, where they are arranged in clusters developed from buds produced on the main axis, and the development of which is probably accelerated or retarded by various conditions, is much more difficult than in *S. rostratum*, where they are produced on a definite raceme, which is early differentiated from the terminal growing

TABLE D.

Cluster..	1	2	3	4	5	6	7	8	9	10	11
PLANT.											
I 1..	A	2b	b, 5p	b, l, p	A	A	A	A	A	b, 2p	2b, 2p
I 2..	l, p	2p	A	3p	p	A	A	2b, 1p	b	A	3b, p
I 3..	p	3p	4p	b, 3p	br, 4p	b, r, p	b, 4p	2b, bl, 3p	2b, br, 2p, a	2b, p, a	b, l, 2p
II—1..	2b	b, 3p, a	b, 2p, a	2b, 3p	2b, 3p	r	2b, br	2b, br	b, r, p	2b, bl	3b
III—1..	3b	2b, p	b, 2p	2b, 2p	b, br, p	b, 3p	b, 3p	4p	b, r, 3p	b, bl, 3p	b, 3p
IV 1..	b	2b, bl	2b, r	2b, bl	3b	3b, br	2b, l	3b	3b	3b	3b
IV 2..	A	b, bl	3b, bl	3b, p	3b	3b, r, p	3b, br	3b, l	4b	4b	4b
V—1..	A	2b, p	b, l, p	b, p	b, r, p	2b, 2p	b, bl, p	b, r, p	2b, r	2b	2b
VI 1..	A	A	A	A	p	2p, a	b, 3p	b, 3p, a	b, r, 3p	2b, 2p	2b, 3p
VI 2..	A	p	b, 3p	b, 2p	2b, 3p	2b, p	b, r, p	2b, p, a	2b, l, p	3b, p	3b, r
VII—1..	b, bl, 2p	2b, 2p	b, l, p	2b, bl, 2p	b, r, 2p	2b, br, p	2b, l, p 2b	3b, bl	3b, r b	3b	3b
VIII 1..	2b	2b	2b	2b	2b	.....	.....	.....	.....	.....	.....
VIII 2..	b	2b, 1p	b, l, p	2b, r, p	3b, br	2b, l b	3b 2b	3b b	.....	.....	.....
IX 1..	2p	b, br, 2p	absent	2b, 3p	b, r, 2p	2b, a	2b, bl	2b, r, p	2b, a	2b, l	3b
IX 2..	b, 3p	2b, 4p	b, l, 3p	2b, 2p	b, 3p	2b, bl, 2p	2b, r	2b, p	b, l, p	2b, bl	3b
IX 3..	A	2b, 3p	2b, p	2b, p, a	2b, 3p	2b, p	b, 2p	l	2b, 2p	b, br, 2p	2b, 2p
IX 4..	A	b, 2p	b, p	b, r, 2p	b, 3p	b, p, a	b, r, 3p	b, 3p	.....	.....	.....
X 1..	2b, 1p	2b	2b, p	b, 2p	br, p	b, br, p	b, bl, r	2b, br	2b	2b	2b
X 2..	A	A	b	b, a	b, p	2b, p	b, r	2b, a	l	2b	2b

point, and at first develops more rapidly than the bud which is to continue the main axis of the branch.[15]

Abundant material in apparently the best condition was found growing around Lake View. Ten plants from this locality were examined, and their condition is here given in tabulated form. In the table following, the number of the plant is given in Roman numerals, the numbers of the branches following it in Arabic numerals. Beginning with the lower portion of the branch and passing upward, the flower clusters are numbered consecutively. These numbers, designated by "cluster," are given in the first line at the top of the table. In the column beneath each of these numbers is shown the condition of the flowers of that cluster on the different branches of the different plants. The table was arranged in this form, not because a comparison of the condition of clusters of the

15. The racemes of *S. rostratum* are produced by a scorpoid sympodial dichotomy of the branch, in which the racemes represent the alternate branches. At first the raceme develops much more rapidly than the bud which is to continue the main stem, and so the racemes, when flowering, are always well towards the outside of the plant.

TABLE D.

14	15	16	17	18	19	20	21	22	23	24	
b, 2p	2b, 2p	3b, 2p	3b, p b	br, 2b, p b	3b, p	2b, br b	3b	3b b	....	.....	6A, 35b, 2br, 2l, 24p.
2b, l, p	2b, bl	2b, r	3b b	2b	2b	.....	.....	.....	.....	.....	4A, 26b, 1bl, 2l, 1r, 11p.
2b, br, a b	2b, 1a	2b	b	2b	.....	.....	.....	.....	.....	.....	23b, 2bl, 4br, 1l, 1r, 31p, 5a.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	22b, 2br, 1bl, 2r, 12p, 2a.
2b, bl	2b, p	2b, r	b	b	2b, 2p b	b, l, p	2b, l b	3b, a	2b, a	2b	41b, 2bl, 1br, 2l, 2r, 34p, 2a.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30b, 2bl, 1br, 1l, 1r.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1A, 31b, 2bl, 1br, 1l, 1r, 2p.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1A, 17b, 1bl, 1l, 3r, 8p.
3b, a	2b, l	3b	3b	3b	3b	.....	.....	.....	.....	.....	4A, 30b, 1l, 1r, 18p, 4a.
3b	2b	.....	.....	.....	.....	.....	.....	.....	.....	.....	1A, 28b, 1l, 2r, 14p, 1a.
2b	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	33b, 3bl, 1br, 2l, 2r, 11p.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10b.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	21b, 1br, 2l, 1r, 3p.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	19b, 1bl, 1br, 1l, 2r, 10p, 2a.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	25b, 2bl, 2l, 1r, 19p.
2b, a	3b	2b	.....	.....	.....	.....	.....	.....	.....	.....	1A, 27b, 1br, 1l, 18p, 2a.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1A, 7b, 2r, 15p, 1a.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18b, 1bl, 3br, 1r, 6p, 1a.
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	2A, 12b, 1l, 1r, 2p, 2a.
											21A, 455b, 18br, 18bl, 21l, 24r, 234p, 22a.

same number is especially desired, but because this seemed the most compact form in which it could be arranged. In the columns under the different clusters, the condition of the flowers is designated as follows: *r*=right-, *l*=left-handed flower; *b*=bud; *br* and *bl* designate buds which are so well developed that it is possible to determine whether they are right-handed or left-handed—these buds will probably open the following morning; a=a bud or flower which has fallen off or failed to develop; A, indicates that the whole cluster has failed to develop. When an axillary cluster is developed it is included in a brace, with the cluster occurring immediately above it, the axillary cluster always being placed below. A seed pod is designated by *p*.

In the last column to the right the condition of each branch is summarized, and finally the grand total is given at the foot of the column.

In table D we have taken into account 241 flower clusters,

and 21 which are either abortive or injured. The number of abortive clusters might be somewhat increased if great care had been exercised in looking for the accessory buds just above the axils of the lowest leaves on the branches. As a rule, however, the first internode or so, if questionable, was omitted. From this it would seem that about eight per cent. of the clusters fail to develop, a percentage which would probably be somewhat increased if care had been exercised in noting the buds where development had been arrested at a very early stage.

On the 10 plants, 14 axillary clusters were produced, being 5.5 per cent. of all the developed clusters. Of these 14 clusters, 2 produced 2 buds each, the others only 1; an average of 1.14 flowers per cluster. The 241 normally developed clusters produced 773 buds, an average of 3.27 flowers per cluster. Of the 773 buds produced on the 10 plants, 22 are found to be injured and fail to develop normally; a percentage of 2.84.

While the series of material is too limited to permit of indulging in generalizations, it might be of interest to note that on 40 plants bearing 332 seed pods, taken from two square feet of ground, September 4, and 3 other plants producing 130 seed pods, taken at the same time, not a single pod developed from an axillary cluster was found. These plants, however, with the exception of the last three, represent all produced on a definite area. It might not be improbable that the smaller, crowded plants would not be so likely to produce axillary clusters as the larger plants growing under more favorable conditions. We may at least conclude from this that the axillary flowers are of little consequence in the seed-producing capacity of the plant.

For the sake of convenience, it has been deemed advisable to summarize in table E the conditions of the flowers and buds which will probably open the day following, as given in table D. From this table, it will be seen that on the day the plants were examined 42 flowers were open—5.4 per cent. of the 773 buds produced on the 10 plants. These flowers as well as the buds, 36 in number, which were to open the next day, are equally divided into right- and left-handed.

The buds which are next to open do not, in any of the cases noted in the above tables, occur on a cluster with flowers which are already open.

TABLE E.

Plant I,	6*r* buds,	3*l* buds,	2*r* flower,	5*l* flowers.
II,	2*r* "	1*l* "	2*r* "	0*l* "
III,	1*r* "	2*l* "	2*r* "	2*l* "
IV,	2*r* "	4*l* "	2*r* "	2*l* "
V,	0*r* "	1*l* "	3*r* "	1*l* "
VI,	0*r* "	0*l* "	3*r* "	2*l* "
VII,	1*r* "	3*l* "	2*r* "	2*l* "
VIII,	1*r* "	0*l* "	1*r* "	2*l* "
IX,	2*r* "	3*l* "	5*r* "	4*l* "
X,	3*r* "	1*l* "	2*r* "	1*l* "
	18*r* buds,	18*l* buds,	24*r* flowers,	21*l* flowers.

There seems to be no law governing the production of right- and left-handed flowers on the opposite sides of the main axis of the plant. Sometimes two right- or left-handed flowers will be produced in succession on one side of the raceme, and sometimes right- and left-handed alternate on the same side.

Concerning the method of pollination in *C. chamæcrista*, the writers have not been able to thoroughly satisfy themselves. Todd says: "I consider the following explanation most probable: In getting the pollen, some grains are dropped on the incurved petal, and by it made to adhere to points of the bee, and to such points in a right-handed flower as will carry it to the stigma of a left-handed flower, and *vice versa*." Robertson[16] says: "The pollen, being thus forced out of the terminal anther pores, falls either directly upon the bee or upon the lateral petal which is pressed close against the bee's side. In this way the side of the bee which is to the incurved petal receives the most pollen. . . . A bee visiting a left-hand flower receives pollen upon the right side and then flying to a right-hand flower strikes the same side against the stigma."

It is very difficult to see just what takes place when the flowers are visited by a large insect, but the writers have observed that when they are visited by honey-bees, for instance, the insect supports itself by hooking his left hind leg over the terminal, upturned portion of the stigma in a right-handed flower, and the right leg in a left-handed flower. The pistil then would serve the function of support for the insect visitor. It was noticed that sometimes bees would attempt to get the pollen by approaching the flower from some direction other than that described above. The insect usually failed in this, and after one or two unsuccessful endeavors would give up the

16. Robertson, Charles, *loc. cit.*

attempt and support itself by placing the leg over the terminal portion of the pistil while it secured the pollen. The function of the incurved petal is not perfectly clear. With an insect well dusted over with pollen from both right- and left-handed flowers, it seems improbable that cross-fertilization in any considerable number of cases should occur from some grains dropped on the incurved pistil.

The writers are not sure that the insect in flying to another flower strikes the tip of the pistil against the side, as stated by Robertson. Certainly, in many cases, the insect, while collecting the pollen, supports itself by placing one leg over the tip of the pistil. When the leg bears a large mass of pollen, which is being stored there, it seems hardly possible that the flowers could fail to be pollinated. It might be suggested that, since the stamens for the most part point in the direction of the incurved petal, the function of this petal is to prevent access to the stamens, except in the cases in which the insect supports itself by means of the pistil. While this seems to the writers, at the present time, the most logical of the two functions so far suggested, much more careful observation work must be done before this point is finally decided. The petal may to a certain extent, in connection with the pistil, serve as support for the insect. Todd and Robertson observed only humblebees visiting the flowers. The writers obtained:

Apis mellifica Linn. Lake View, August 7. Seven specimens.
Agapostemon texanus Cress. Lake View, August 7.
Mellisoides bimaculata (St. Farg) Lepl. Lake View, August 7.
Megachile petulans Cress. Lake View, August 7.
Bombus separatus Cress. Lake View, August 7.

As in the case of *Solanum*, it will be seen that the collecting period extended over a very short period of time. More search would doubtless greatly increase the list.

Robertson reports the following species as collecting pollen: *Bombus virginicus* Oliv., *B. separatus* Cress., *B. americanorum* F., and *B. scutellaris* Cress.

August 28, when the blossoming season for *C. chamæcrista* was almost over, an examination of material from the above-named region was made for the purpose of determining the number of seeds produced by a single plant. Fifteen pods were selected

at random from different plants and the number of ovules counted. It was impossible to tell about the number in each pod which were fully and normally developed seeds or which would become such; consequently this factor is not taken into consideration. The percentage of ovules which fail to develop is, however, small. The number of seeds found to the pod is shown by the following:

TABLE F.

Pod I, 13 seeds.	Pod X, 14 seeds.
II, 14 "	XI, 17 "
III, 11 "	XII, 18 "
IV, 11 "	XIII, 17 "
V, 10 "	XIV, 15 "
VI, 12 "	XV, 14 "
VII, 16 "	
VIII, 12 "	Total XV, 202 seeds, or 13.4 per pod.
IX, 8 "	

From this it will be seen that the minimum number of seeds found was 8, the maximum, with an average of 13.4. Since the pods were simply gathered at random, there is no certainty of gaining the maximum or minimum number of seeds, but a fair average of the number produced may be expected. September 4 three plants were examined to determine something about the range of variation in the number of ovules produced in the pods of a single plant. The results are given as follows:

Plant 1 varies from 5 to 11.

Plant 2 varies from 8 to 18.

Plant 3 varies from 9 to 14.

Plant 1 had 35 pods, plant 2 had 64, and plant 3 had 27.

Plant 1 was selected on account of the small number of seeds produced per pod.

It will be seen from table D that an average of nearly 3.3 flower buds per cluster is produced. These were moderate-sized, healthy plants, producing on the whole probably more than the average number of clusters per plant. On the ten plants, there were produced 342 clusters, which bore 344 seed pods, instead of about 1120, the number of flowers which might be expected, thus giving less than thirty-three per cent. of the buds which produce mature seed pods.

It will be seen that, while in the observations made on *S. rostratum* the flowers which failed to produce seed did not reach much over six per cent., in *C. chamæcrista* it is over sixty per

cent. In addition to this fact, it is rare to see a seed pod of *S. rostratum* which has been destroyed by insects or other destructive agencies, while in 460 pods of *C. chamæcrista* which were examined at Lake View, September 4, not one was found which did not have some of the ovules destroyed by the larvæ of some insect, and probably this would amount on the average to fifty per cent. of all the seeds produced, being in the case of some plants as high as seventy-five per cent.

A convenient method of approaching the question of the production of seeds might be to determine the number of seed pods produced on a given area of ground. A general idea may be obtained from the examination of the plants growing upon two square feet of ground. In the first case, the plants were much crowded; in the second, not nearly so much so; in fact, it may be said they were growing under "normal" conditions. It might be interesting to compare the results. The material for the two tables was taken September 4.

FIRST SQUARE FOOT.

Plant	1,	pods	0	Plant	16,	pods	10
"	2,	"	10	"	17,	"	2
"	3,	"	4	"	18,	"	0
"	4,	"	13	"	19,	"	0
"	5,	"	0	"	20,	"	0
"	6,	"	12	"	21,	"	0
"	7,	"	3	"	22,	"	6
"	8,	"	1	"	23,	"	1
"	9,	"	4	"	24,	"	5
"	10,	"	3	"	25,	"	2
"	11,	"	0	"	26,	"	3
"	12,	"	25	"	27,	"	0
"	13,	"	2	"	28,	"	3
"	14,	"	0				
"	15,	"	0	Total,	28,	pods	109

SECOND SQUARE FOOT.

Plant	1,	pod	1	Plant	8,	pods	11
"	2,	"	50	"	9,	"	9
"	3,	"	36	"	10,	"	3
"	4,	"	15	"	11,	"	0
"	5,	"	48	"	12,	"	7
"	6,	"	34				
"	7,	"	9	Total,	12,	pods	223

In the first square foot of ground, where the plants were much crowded, of the twenty-eight plants, ten produced no seed pods at all, and of the remaining eighteen only six produced over five each. On these plants an average of a little less than four pods per plant was produced. In the second lot, where, evidently,

the plants were not nearly so crowded, only four produced fewer than five seed pods, and there was a general average of 18.7 pods per plant.

On the first foot of ground, then, there might be produced in the neighborhood of 1300 seeds; on the second, 2600. The large *Solanum* upon which 40,000 seeds were estimated would probably cover an area of 12.5 square feet, giving 3200 seeds per square foot. Of course, these figures represent only certain isolated cases, which in a way are typical, but must not be taken to represent the average condition.

The largest plant noted September 4 had produced 100 pods, with an average of thirteen seeds per pod; this plant might show 1300 seeds.

Professor Todd discusses in his paper the occurrence of similar divergences from the typical form in other Solanaceæ and Leguminosæ, and tries to discover some hint as to their origin. Lack of material for observation precludes any present discussion of these points.

The results of these observations may be briefly summarized as follows:

Solanum rostratum.

1. As Professor Todd observed, the numbers of right- and left-handed flowers on a plant of any considerable size are about equal.

2. As a general rule, only one flower opens at a time on a raceme, but very commonly two will open on the raceme the same morning, giving a right- and left-handed flower opening simultaneously, and thus permitting in a considerable number of cases pollination between flowers on the same raceme, even if Professor Todd's theory of the method of pollination be the correct one.

3. Even on the smaller branches of the plant, the flowers are almost always approximately divided into the two types.

4. The flower has a distinct odor.

5. Various species of insects visit the flowers for pollen. Many insects secure pollen without effecting pollination.

6. In a rather hasty microscopic examination, no very apparent difference was detected between the pollen from large and small stamens.

7. A very important function of the observed arrangement of

stamen and pistil in *S. rostratum* seems to the writers to be that of support for the visiting insect.

8. It might seem that the pollen from the small stamens is of much more importance in the process of fertilization than Professor Todd suspected, especially since it seems that there is much more certainty of the pollen from the small stamens reaching the pistil than there is of that from the large stamen. The fact that there is some question as to the fertility of the pollen from the large stamen in all cases, and that in the case of another plant stamens of somewhat similar arrangement seem to have lost entirely their direct reproductive function, would indicate the same.

9. In a limited number of cases the pollen from the large stamen of a flower seems to be fertile on its own stigma, as well as upon the stigma of a flower opening simultaneously on the opposite side of raceme.

10. Spontaneous self-pollination seems sometimes to occur.

11. The percentage of cases in which seeds develop in those flowers in which artificial pollination is effected in the same flower or in two flowers of the same raceme is much smaller than when cross-pollination is effected by insects, reaching, in the case of the somewhat limited experiments of the writers, only as high as 28.5 per cent. Whether this is partially due to the method of applying the pollen or not has not been determined; whether the seeds produced by these cases of pollination of the same flower or flowers on the same raceme are capable of germination or not has not yet been determined. It might be suggested that the low percentage of cases is due to a lack of fertility in the pollen of the large stamen.

12. Estimated from the number of seed pods which normally develop, the number of flowers in which pollination is not effected is very small, not reaching, in the observations of the writers, much over six per cent.

Cassia chamæcrista.

1. Right- and left-handed flowers are produced at the same time on the plant. When several plants are taken, the number of right- and left-handed flowers produced is practically the same.

2. So far as observed, two flowers were never seen open at

the same time on a cluster, nor was a bud ready to open the following morning ever found on a cluster with an open flower. Thus, cross-pollination between flowers on the same cluster would not be possible, as it frequently is in *S. rostratum*.

3. So far as the writers have been able to ascertain, there is no law governing the producing of right- and left-handed flowers on the opposite sides of the main axis.

4. Various species of insects visit the flowers for pollen.

5. It seems that pollination is effected in many cases by the transfusal of pollen from the leg of the insect, where it is being carried, to the stigma of the stamen upon which it is supporting itself. The function suggested by Professor Todd for the incurved petal seems to the writers entirely improbable.

BOTANICAL LABORATORY, UNIVERSITY OF KANSAS,
SEPTEMBER 28, 1901.

EXPLANATION OF PLATE I.

Solanum rostratum Dunal.

Fig. 1. Right-handed flower from the front and a little to one side, showing large and small stamens, pistil, and wings of the corolla, which enfold pistil and large stamen in the bud. × 2.

Fig. 2. Tip of a raceme from the front, showing one left- and two right-handed flowers; also the decurved end of the raceme, with the buds.

Fig. 3. Lateral view of decurved tip of raceme, showing the buds.

Fig. 4. Lateral view of bud ready to open the following morning, showing the two lower lobes of the corolla, enfolding pistil and large stamen.

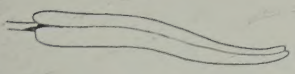
Fig. 5. Ovary and pistil. × 5.

Figs. 6 and 7. Lateral and dorsal view of large stamen. × 5.

Figs. 8 and 9. Lateral and dorsal view of small stamen. × 5.

Figs. 10 and 11. Hind leg of *Bombus*, with and without mass of pollen.

PLATE I.



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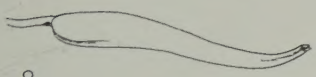

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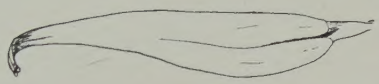

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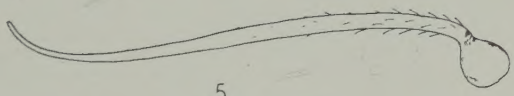

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